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MAKING STARCH FROM WHEAT FLOUR

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Introduction

More than a year ago it became apparent that a shortage of corn was developing on the cash market. The importance of such a shortage to the starch industry is obvious when we consider that about 98 percent of the starch normally produced in the United States is obtained from corn by the wet-milling process. At the same time that this shortage of corn was looming on the horizon, the demands were increasing for starch and its conversion products--sirups and sugars. These products were being used more and more both in food and in essential industries.

This combination of a threatened shortage of corn and increased demand for starch products led to interest in the possibilities of using other cereal grains besides corn as raw materials for starch production. Subsequent studies at the Northern Regional Research Laboratory have led to the development of two processes for the production of starch, using wheat flour as raw material. In these studies emphasis was placed on the development of procedures that would require a minimum of equipment or that would be adaptable to existing plant facilities.

Wheat, from the standpoint of availability, price, and ease of processing, is the closest competitor of corn as raw material for the production of starch. In certain regions, such as the Pacific Northwest, the production of starch and sirups from wheat appears particularly attractive. In the Pacific Northwest during the past decade soft wheat has been a burdensome surplus. Its price has been about the same as, and in some years even less than, the Chicago market price of corn.

Wheat Flour as Raw Material

Let us consider briefly some of the advantages and disadvantages which wheat flour might offer as a raw material for starch production. Flour can be processed more rapidly than the whole grain, and in less plant space, because of the elimination of the steeping and grinding steps necessary, for example, in the wet-milling of the grain. The use of flour also simplifies the problem of byproduct recovery since much of the bran and fiber is separated at the flour mill. Another advantage of flour is its high starch content; straight wheat flour contains, on a moisture-free basis, about 76 to 81 percent starch.

One of the more apparent disadvantages of flour is its higher cost. However, the difference in price between flour and the grain, when calculated on the basis of the starch content, has nearly disappeared during the past couple of years. Another disadvantage, which applies in general to wheat as compared with corn, is the lack of byproduct oil recovery which is of value in the corn starch industry.

Particularly under present circumstances, when processing equipment is a major bottleneck, the advantages in the use of wheat flour instead of grain probably outweigh the disadvantages. We shall therefore limit our discussion to the use of wheat flour as a potential raw material for maintaining or increasing the production of starch and its conversion products.

Methods of Starch Production from Wheat Flour

We shall not take the time to discuss the details of the history and known methods of wheat starch production. Suffice it to say that relatively little information is available, either in patents or in other publications, concerning the industrial preparation of starch from wheat flour. For most of the processes which have been used or proposed, necessary details are usually lacking with regard to the procedures used, the yields and purity of the products obtained, and on the adaptation of the processing steps to modern methods and equipment.

Let us turn immediately to the two processes to be described. They are designated as the Alkali Process, which is a chemical process, and the Batter Process, which can be looked upon as a mechanical process since it uses no chemicals other than water for starch separation.

I. Alkali Process

The Alkali Process is dependent on the protein-dispersing action of dilute alkali. The relationship on which this process is based is well shown in figure 1. This curve shows the relation between the percent of flour protein dispersed and the pH of the mixture of flour and dilute aqueous sodium hydroxide. You will note that as the pH of the mixture is increased the extent of dispersion increases rapidly. For this discussion, by "dispersed" we mean that the protein is in such a form that it fails to settle out by gravity or moderate centrifugal force over a reasonable period of time. At about pH 10.5 and higher, essentially 100 percent of the wheat flour protein is in solution or dispersion. For a basis of comparison, a pH of about 10.3 to 10.6 is obtained when you mix 1 part flour with 10 parts of 0.01 N. NaOH solution.

With the protein completely dispersed one has only to separate the starch by settling, tabling, or centrifuging, with appropriate washing, to obtain all of the starch from the flour nearly free of protein.

Centrifuge Procedure for Starch Preparation

In figure 2 is shown a flow sheet of the processing steps which were adopted for starch preparation on the basis of the alkali treatment of wheat flour.

The process consists essentially of: First, treatment of the flour with enough dilute alkali to completely disperse the protein. This usually involved a pH of between 10.8 and 11.8, a quantity of dilute alkali equal to 6 to 12 times the weight flour, and a temperature of not over 35° C. We have used sodium hydroxide for our main studies because it is efficacious, economical, and readily available. The second step is the separation of the starch from the alkaline protein solution by centrifuging, as indicated in figure 2, or by tabling. Third, purification of the starch by washing if required for the end use intended for it. Finally, recovery of byproduct protein by precipitation when the alkaline solution is acidified to about pH 5.5 with sulfuric or other acids.

A fair amount of variation is possible in the conditions and methods used. We shall limit the discussion, however, to the general centrifuge procedure as applied to various flours. The conditions were chosen to fit a large variety of raw materials without need for alteration.

For the preparation of starch by the centrifuge procedure, 1 part flour (on a moisture-free basis) was mixed with rapid stirring with 6 parts of 0.03 N. sodium hydroxide solution. Such a mixture usually had a pH between 10.8 and 11.2 and contained, on the basis of the weight flour, 0.75 percent sodium hydroxide. For a few flours, additional water was required for best results. The mixture was stirred until all the lumps had disintegrated--this usually took less than 15 minutes. Even on pilot plant runs with 50 pounds of flour and not very efficient stirring, half an hour was sufficient.

The flour suspension, having a Baume' of about 8°, was then run into the imperforate basket of a centrifuge. This was done at such a rate that the overflow liquor was essentially free of starch. The cake of crude starch was resuspended in a quantity of water equal to the volume of liquid used initially. The starch was again separated in the imperforate basket of the centrifuge. The resulting starch cake was dried at 40° C. and pulverized.

For recovery of byproduct protein the alkaline liquor from the first centrifuging was acidified to pH 5.5 with dilute sulfuric acid. The precipitated protein was separated by centrifuging and dried at 40° C. without washing.

Products Obtained By the Alkali Process

For convenience, we shall discuss separately the starch and protein obtained in this manner.

Starch

In table 1 are shown representative examples of the starch prepared by this procedure. These starches were obtained from straight flour from three classes of wheat and also from a second clear flour, which is a low-grade flour fraction, and from a sample of granular wheat flour.

The yield of once-washed starch naturally parallels the starch content of the flour. For the straight flours the yield corresponded to 81 to 86 pounds of product per 100 pounds of flour.

The amount of starch actually in this product was from 94 to 98 percent by analysis. This lowered purity is caused by the other alkali-insoluble solids which come down with the starch. These constituents are largely cell-wall fragments and fine bran.

The protein content of the products from the straight flours was 0.3 to 0.4 percent, which is fairly low. The last two products have a higher protein content, possibly because of the cellular material still present.

The starch thus obtained is suitable for conversion to sirups or sugars, or for fermentation. It is preferably used in the wet state since it does not dry or handle as nicely as a tabled starch.

Byproduct Protein

In table 2 are given the recoveries of byproduct protein for the same flour samples. You will note that 62 to 78 percent of the protein in the flour is recovered in this fraction. The protein content of the dried product is quite high--70 to 87 percent. This is a denatured protein--it has lost its gluten properties. This byproduct protein has been shown to be very satisfactory for production of monosodium glutamate.

Other Cereal Starches

Table 3 gives a further indication of the range of raw materials on which the alkali process can be used. Here we have the yield and purity of the once-washed starch obtained by the centrifuge procedure from the flour of barley, rye, oats, and rice. These flours were prepared on an experimental Buhler wheat mill. You will observe that the protein content of the starch is low for all but rice.

Rice flour contains hard particles from which the protein is probably more difficult to remove. It may also be that the protein is not entirely alkali-soluble under the conditions used.

Tabling Separation of Starch

When a very high-quality dry starch is desired, the flour dispersion can be tabled. For this procedure 12 parts of 0.03 N. NaOH are used instead of 6 parts. The prime-quality starch settles on the table while the fiber, gelatinized granules, and many small granules remain suspended and flow over the end of the table. These solids are separated by centrifuging and called tailings starch.

Typical results of such treatment are shown in table 4, the distribution between the two fractions being dependent on the tabling conditions. The tabled starch was washed once by retabling, then filtered and dried. The centrifuged tailings starch was twice resuspended and centrifuged to wash it.

The tabled starch yields, equivalent to 55 to 67 pounds of starch per 100 pounds of flour, represent around 72 percent of the total starch in the flour, except for the 83 percent recovery with American Banner wheat flour. Note the very low protein content of the tabled starch, 0.2 to 0.3 percent.

The tailings starch is also quite low in protein, although the total "purity" is lowered considerably by the higher concentration of cell-wall debris. This fraction is preferably used for conversion or fermentation since it dries with difficulty to a somewhat horny product.

The tabled starch dries nicely and is equal in purity to high-quality commercial starches.

These tabling results obtained in the laboratory were found to be essentially duplicated when runs were made in the pilot plant using 50 pounds of flour for each run.

II. Batter Process

Let us turn now to the second process, which we have called the Batter Process. The name is derived from the fact that, as the first step, the flour is mixed with water to form a batter or fairly thin dough, in contrast to the stiff dough used in the well-known dough-washing procedure for the preparation of wheat gluten. The process involves the mechanical separation of starch from essentially unaltered wheat gluten.

Figure 3 gives the flow sheet for the Batter Process as used in most of the studies. This process is based on the preparation of a fairly cohesive and elastic batter of flour and water. In this batter the starch is held in a rather soft, semi-fluid matrix of gluten. When a batter of the proper consistency is vigorously stirred in water, it is mechanically torn apart into small pieces. The action of disintegration or tearing apart of the batter exposes a very large surface area so that the starch is almost instantaneously and quite completely washed out of the gluten network. The remaining gluten in the particle pulls together and forms a fairly compact elastic lump or "curd" of gluten. This gluten curd is then quite resistant to further disintegration by the stirring. The resulting slurry of gluten curds and starch milk can be pumped onto a mechanical screener to separate the gluten nearly quantitatively from the starch milk. The products, starch and gluten, may be further processed as required for the use to which they are to be put.

The important thing in the process is to have a batter which disintegrates to give gluten curds which are small enough and soft enough to allow very rapid washing-out of starch, yet big enough to be retained on the screen. The batter desired, in general, is smooth, semi-fluid, and somewhat elastic and cohesive.

Two factors which govern the type of batter necessary to get the results just indicated are (1) the size of gluten curds desired, and (2) the type of stirring or vigor of disintegration in the second step.

In general, screens of from 60 to 163 meshes to the linear inch have appeared most satisfactory. However, as large an opening as in a 16-mesh screen has been used. For preparation of highest-quality starch we usually used a No. 17X silk screen, which is about 163 mesh.

In the disintegration step a definite tearing action on the batter is advantageous so that simultaneously the batter is broken up and the starch released. The more efficient the disintegration, the more resistant the batter must be toward tearing apart; otherwise the gluten curds will be too small to be held on the screen.

Control of Batter Quality

Several factors influence the quality of the batter, that is, its resistance toward disintegration. These variables are interdependent, so that changes in one can be counterbalanced, in general, by changes in another.

We wish simply to enumerate the factors which tend to give a batter which is more resistant to disintegration.

The amount and inherent quality of the gluten in the flour will determine the type of batter obtained under given conditions. Higher gluten content and better quality gives a more resistant batter. Conversely, flours with only 6 to 7 percent protein apparently do not have enough gluten to form a continuous network, since the batter fails to give gluten curds.

The more efficient and longer the mixing of the batter, the more resistant it is to disintegration. Many types of mixers can be used, such as paddles (by hand), planetary mixers, Baker-Perkin type mixer with Z-blades, or gate stirrers. Once the water is uniformly incorporated with the flour, simple standing has the same effect as longer mixing, although the action is slower.

The ratio of water to flour for most of our runs was between 1 and 1-1/4 parts water for each part of dry-matter flour. That is, the moisture in the flour was included as part of the water being added when the ratio was calculated.

Finally, a higher temperature of the water (staying below the starch gelatinization temperature) gives a more resistant batter. The usual range used was 25° to 40° C.

Experimental Procedure

To illustrate the practice of the Batter Process let us consider an experimental run in the laboratory on a straight flour containing 12.4 percent protein and 80 percent starch on the moisture-free basis.

Flour equivalent to 1 kilo of moisture-free solids was mixed with enough water to give a total of 1.1 kilo of water (including the moisture of the flour). Tap water at 54° C. was used so that the final batter was at 40° C. The flour was added to the water while stirring, or the two were placed together in the container at the start and mixed rapidly so that no lumps of incompletely wetted flour or stiff dough were formed. In the laboratory, on this 1 kg. scale, the mixing was for 1 minute, vigorously, with a hand paddle, or 7 minutes in a Hobart mixer at slow speed.

To this batter was immediately added 2.9 kilo of tap water at 40° C., giving a total of 4 kg. water per kg. of dry matter, so that the final starch slurry would be about 10° Baume'. The batter was then disintegrated by a high-speed propeller stirrer for 1 minute. The gluten which at first tends to wrap around the shaft was pulled off by hand during stirring.

The slurry of gluten curds and starch milk was screened on No. 17X silk (163 mesh) on a gyratory shaker. The gluten mass was rinsed twice by hand and dried. In practice, one would probably spray water on the screen to prevent the gluten from carrying starch milk with it.

The starch milk was centrifuged in bottles and the supernatant liquor decanted. The resulting crude starch was dried without washing.

Products Obtained By the Batter Process

In table 5 is shown the yields and analysis of the products obtained in this way. You will note that 80 percent of the weight flour is recovered as centrifuged crude starch. This fraction contains 96 percent of the starch initially in the flour. This crude starch has a protein content of only 0.8 percent, which is lowered to 0.6 percent by a single washing. Because of the fiber and other materials present, the starch content is 95 percent.

When a starch milk obtained in the same way was tabled, about 77 percent of the total starch in the flour was recovered on the table. This was a prime-quality starch containing only 0.3 percent protein. It was comparable to high-grade commercial starches.

The crude gluten, equivalent to 14 pounds from 100 pounds of dry-weight flour, contains 85 percent of the total flour protein, and only 3 percent of the total starch. Analysis of the dried product showed a protein content of 75 percent and a starch content of 18 percent.

Only 5 percent of the total solids were in the soluble fraction.

Table 6 gives an indication of the range of applicability of the Batter Process. The straight flours gave a gluten recovery averaging 85 percent. The purity of 63 to 78 percent is partly dependent on the extent and vigor of rinsing.

For the last two raw materials the results were not as good, particularly from the standpoint of starch purity. However, it is apparent that even these materials can be used where only a partial removal of protein is necessary.

Evaluation of Processes

From the standpoint of quantity and quality of starch produced, the Alkali and the Batter Processes are about equal. Although the processes serve substantially the same purpose, each does enjoy certain advantages as regards applicability to raw materials and type of products produced.

The Alkali Process is advantageous in its applicability to a wide variety of raw materials. Straight and clear grades of flour from all varieties of both soft and hard wheat may be used, while granular wheat flour is suitable when the centrifugal rather than the tabling separation is used. Rye, barley, oat, and rice flours may also be processed in essentially the same manner, although the recovery of byproduct protein is usually less satisfactory. The byproduct protein recovered by this process is, of course, a denatured protein.

The Batter Process has been found applicable to all types of wheat flours or ground wheat, except those having the very lowest protein content. The advantages of this process lie in the speed and simplicity of operation, requirement of no chemicals, and practically complete recovery of the wheat gluten in easily handled form. The wheat gluten may be vacuum-dried to give a "native" or "gum" gluten, or drum-dried to give a denatured protein.

The amount and kind of equipment needed for either process will vary according to the type of products produced and the degree of refinement required for the projected end-use of these products. The least amount of equipment would be required, for example, in producing starch slurries or wet starch without further refining. Such a product could then be used for fermentation purposes or for the production of less highly refined sirups. These processes could therefore be used advantageously in plants where the facilities are already available for fermentation or for processing the starch-conversion products.

The Alkali and Batter Processes could be employed in beet sugar factories and sugar refineries for the production of starch for conversion into sweetening agents. The amount of new installations required would be greatly reduced since these plants already contain nearly all the equipment necessary for the processing of the starch-conversion liquors in the production of sirups. Since beet sugar factories operate seasonally, the production of sirups could be carried out during the off-season, permitting year-around operation of the plants. It is for this type of application that these processes appear particularly feasible.

Figure 1

Relationship of wheat protein dispersion to the pH of the mixture of flour and sodium hydroxide

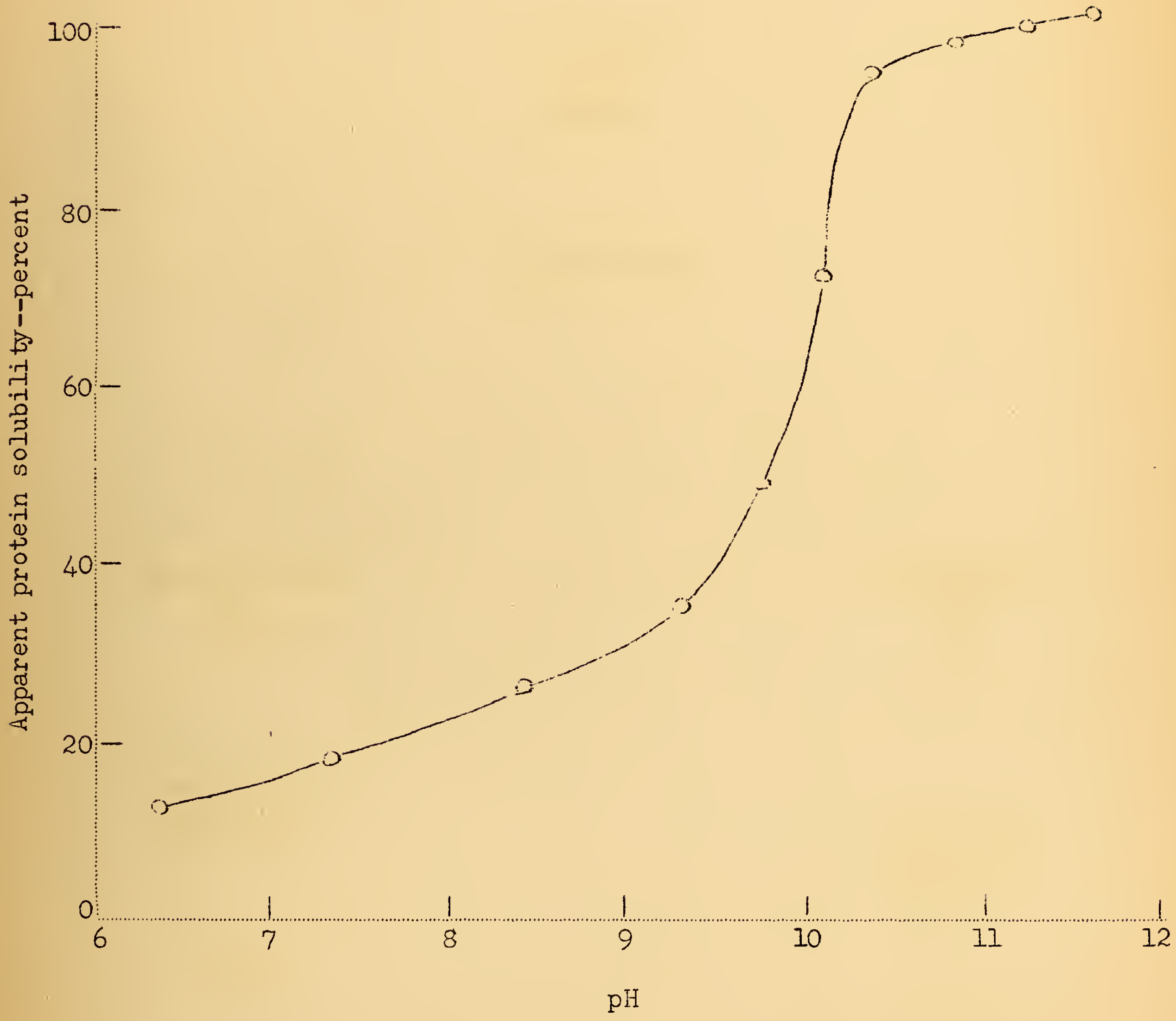

Figure 2

ALKALI PROCESS FLOW SHEET

Centrifuge Procedure

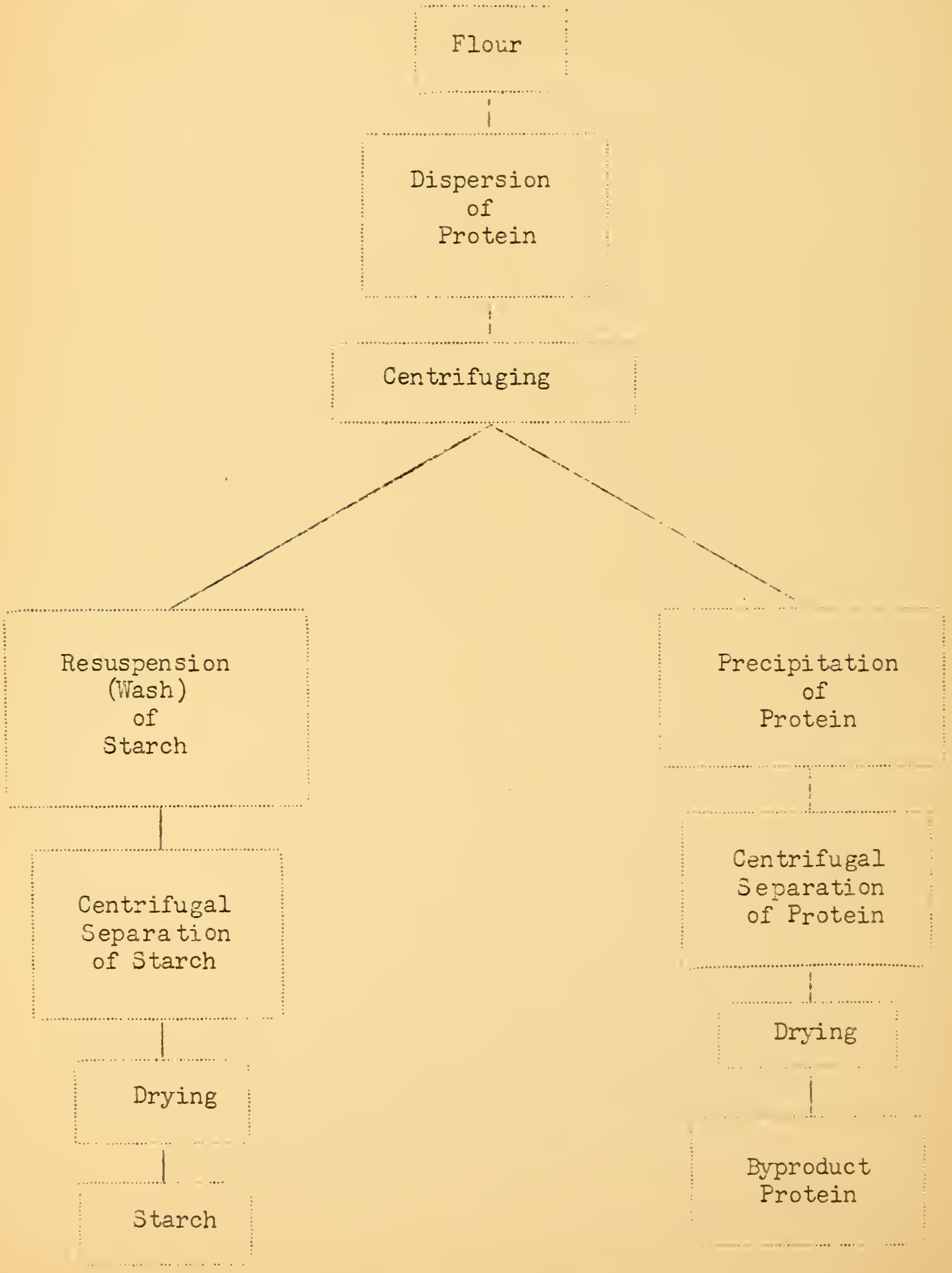

Figure 3

Batter Process Flow Sheet

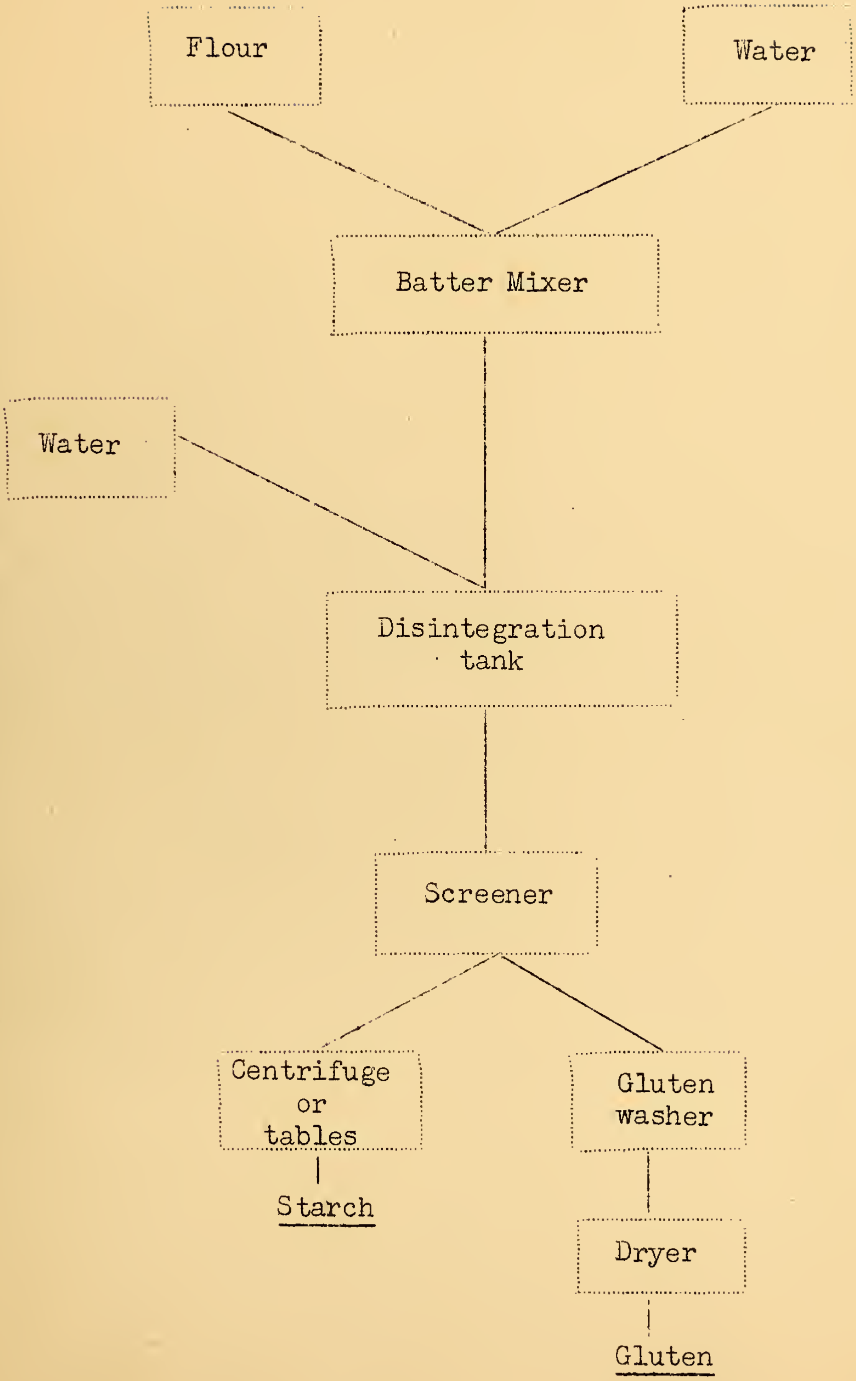

Table 1

ALKALI PROCESS

Centrifuged wheat starch[1]

Wheat flour	Starch (washed once)			
	Yield	Starch content	Protein content	Starch recovery
	Lb. per 100 lb.	Percent	Percent	Percent
Rex soft white	86	96	0.3	101
No. 2 Hard Winter[2]	83	98	0.4	101
No. 2 Dark Northern Spring[2]	81	97	0.4	100
Second clear, from hard red spring wheat	71	95	1.0	105
Granular wheat flour	81	94	1.1	98

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[1] All data on moisture-free basis.

[2] From Commodity Credit Corporation.

Table 2

ALKALI PROCESS

Byproduct protein from centrifuge procedure[1]

Wheat flour	Precipitated protein		
	Yield	Protein content	Protein recovery
	Lb. per 100 lb.	Percent	Percent
Rex soft white	6	70	63
No. 2 Hard Winter[2]	10	87	71
No. 2 Dark Northern Spring[2]	11	87	66
Second clear, from hard red spring wheat	20	82	78
Granular wheat flour	9	87	62

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[1] All data on moisture-free basis.

[2] From Commodity Credit Corporation.

Table 3

ALKALI PROCESS

Centrifuged starch from various cereal flours[1]

Cereal grain	Starch content of flour	Starch (washed once)		
		Starch recovery	Starch content	Protein content
	Percent	Percent	Percent	Percent
Trebi barley	79	99	95	0.5
White rye (commercial)	76	101	96	0.4
Fulton oats	72	98	94	0.6
Colusa rice	92	97	97	1.0

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[1] All data on moisture-free basis.

Table 4

ALKALI PROCESS

Starch recovery by tabling procedure[1]

Wheat flour	Tabled starch			Tailings starch	
	Yield	Starch recovery	Protein content	Starch content	Protein content
	Lb. per 100 lb.	Percent	Percent	Percent	Percent
Rex soft white	59	73	0.2	90	0.5
American Banner soft white	67	83	0.2	93	0.5
No. 2 Hard Winter[2]	57	72	0.3	93	0.4
No. 2 Dark Northern Spring[2]	56	71	0.3	88	0.4
Thatcher hard red spring	55	72	0.3	94	0.5
Second clear, from hard red spring wheat	44	68	0.2	79	0.7

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[1] All data on moisture-free basis.

[2] From Commodity Credit Corporation.

Table 5

BATTER PROCESS

Application to straight flour from No. 2 Hard Winter Wheat[1]

Products	Recoveries			Analyses	
	Total solids	Starch	Protein	Protein content	Starch content
	Percent	Percent	Percent	Percent	Percent
Centrifuged crude starch	80	96	5	0.8	95
Crude gluten	14	3	85	75	18
Soluble solids (in supernatant from starch)	5	0	9	23	0
Total	99	99	99		

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[1] All data on moisture-free basis.

Table 6

BATTER PROCESS

Wheat gluten recoveries from various flours[1]

Wheat	Protein content of flour	Crude gluten	
		Protein recovery	Protein content
	Percent	Percent	Percent
Chiefkan hard red winter	14.7	87	63
Turkey hard red winter	13.4	87	70
Fulhio soft red winter	12.2	83	76
Soft red winter (commercial milling)	10.7	81	75
Thatcher hard red spring	18.7	85	78
Baart hard white	14.3	86	74
Pentad red durum	17.1	85	75
Ground whole, No. 2 Hard Winter	13.9	68	68
Granular wheat flour	12.8	68	65

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[1] All data in percent, on moisture-free basis.